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Homer City Multistream Coal Cleaning Demonstration A Progress Report

Pennsylvania Electric Co., Johnstown

Prepared for

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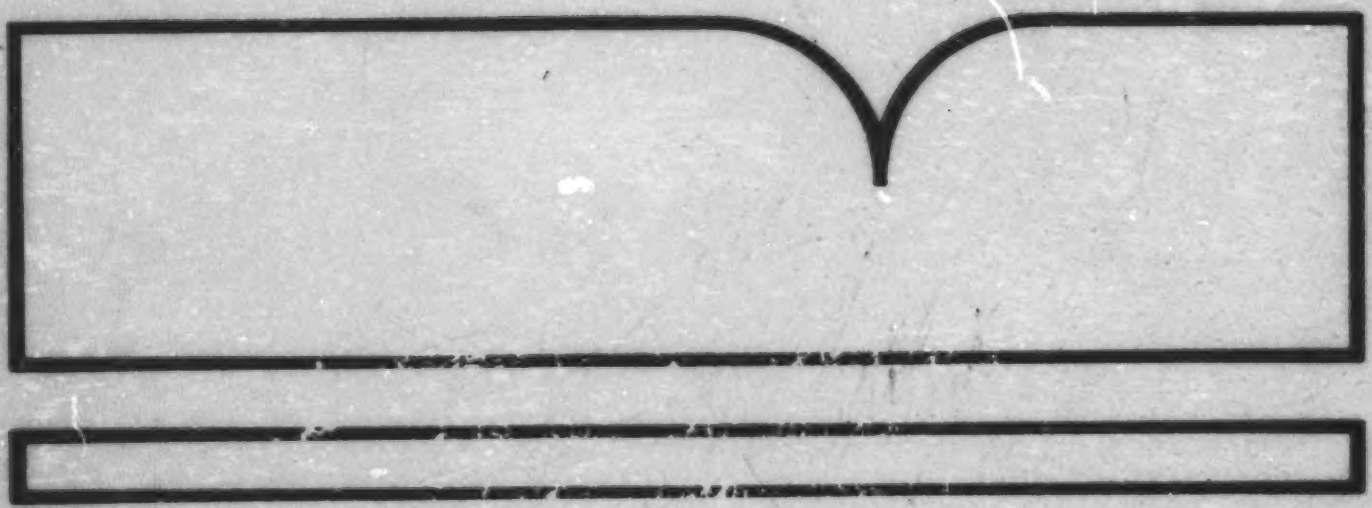

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HOMER CITY MULTISTREAM COAL CLEANING DEMONSTRATION: A Progress Report

by

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Pennsylvania Electric Company
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16. ABSTRACT The report gives an overview of ongoing testing and evaluation of the Homer City Coal Cleaning Plant, built to enable the Homer City Power Complex to meet sulfur dioxide (SO_2) emission levels mandated by the State of Pennsylvania and the U. S. Government. The plant was constructed as a result of an extensive comparative evaluation of flue gas desulfurization (FGD) and physical coal cleaning. The Homer City System, the Multistream Coal Cleaning System (MCCS), was chosen as an economical alternative to FGD. The plant contains circuits for cleaning coarse, medium, and fine coals and for recovering fine and very fine coals. The dominant type of cleaning equipment used in the plant is the dense medium cyclone. The original '93 plant' c nfiguration was never able to clean coal to the conditions specified in the plant design. An extensive test and evaluation program was begun to identify and correct the causes of plant operating problems. After extensive pilot plant equipment tests and engineering studies were completed, recommendations were made for plant modifications necessary to correct the design and operating deficiencies of the plant. Extensive modifications were made to one of two parallel processing trains in the plant (the 'B' circuits), and a test program was initiated to evaluate these corrective measures. The modified 'B' circuits have not yet met design conditions.

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August 9, 1984
Date

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NOTICE

This document has been reviewed in accordance with U.S. Environmental Protection Agency policy and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

ABSTRACT

This Interim Progress Report presents an overview of the ongoing testing and evaluation of the Homer City Coal Cleaning Plant, built to enable the Homer City Power Complex to meet sulfur dioxide (SO_2) emission levels mandated by the Pennsylvania and Federal governments.

The plant was constructed as a result of an extensive comparative evaluation of flue gas desulfurization and physical coal cleaning. The Homer City System, The Multi-Stream Coal Cleaning System (MCCS), was chosen as an economical alternative to flue gas desulfurization.

The plant contains circuits for cleaning coarse, medium, and fine coal and for the recovery of fine and very fine coal. The dominant type of cleaning equipment used in the plant is the dense medium cyclone.

The original "93 plant" configuration was never able to clean coal to the conditions specified in the plant design. An extensive test and evaluation program was begun to identify and correct the causes of plant operating problems. After extensive pilot plant equipment tests and engineering studies were completed, recommendations were made on plant modifications necessary to correct the design and operating deficiencies of the plant. Extensive modifications were made to one of two parallel processing trains in the plant (the "B" circuits) and a test program was initiated to evaluate these corrective measures.

The recently modified "B" circuits have not yet met design conditions. Presently, the fine and medium coal circuits are undergoing an evaluation to determine why the cyclones are not operating at predicted levels and to test further proposed corrective actions in actual operation.

A second series of plant modifications is scheduled for the "B" circuits between mid-1984 and early 1985. In this phased-in approach, each of the major remedial installations will be optimized at the preparation plant in a spliced-in trial mode before a full modification of the circuit is authorized. Current optimization work has already produced a cyclone circuit for cleaning fine coal that demonstrates a 40 percent improvement in efficiency when compared to the existing circuit cyclones during low gravity operation.

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The authors wish to acknowledge the active participation of the EPA Project Officer in the preparation of this report.

Table of Conversion Factors

Multiply English Unit	by	To Obtain SI Unit
pound (lb)	453.59	gram
ton (2000 lb)	0.907	megagram (Mg) = metric ton
inch (in.)	0.0254	meter (m)
foot (ft)	3.048	meter (m)
British Thermal Unit (Btu)	1054.88	Joule (J)
Btu/lb	2.326	J/g
$lb/10^6 Btu$	429.907	ng/J
gallon/minute (gpm)	0.06309	liter/second (l/s)

Tyler Screen Size Mesh Openings

Mesh Size	in.	mm
14	0.0469	1.18
24	0.0234	0.60
48	0.0117	0.30
100	0.0059	0.15
200	0.0029	0.075
270	0.0021	0.053
325	0.0017	0.045

INTRODUCTION

The Homer City Power Complex is a mine-mouth power plant with three coal-fired boilers. The facility began commercial operation in 1969 with two 600 MW units (Units 1 and 2). A 650 MW boiler (Unit 3) was put into commercial operation in December, 1977. The power station obtains approximately 60 percent of its coal from two dedicated mines at the plant site. The remaining coal is purchased from other mines within 30 miles of the power station.

Units 1 and 2 must comply with an SO_2 emission limit of 3.7 $lb/10^6$ Btu (1590 ng/J), as prescribed by the Pennsylvania Department of Environmental Resources (Pa.DER). Unit 3 must comply with Federal New Source Performance Standards (NSPS) which limit SO_2 emissions to 1.2 $lb/10^6$ Btu (516 ng/J).

The owners of the Homer City Power Complex initially considered two different strategies for complying with these emission regulations. The first involved using cleaned coal in Units 1 and 2 and installing a flue gas desulfurization system (FGD) on Unit 3. The second strategy called the Multi-Stream Coal Cleaning System (MCCS) involved the construction and operation of a coal preparation plant to produce compliance coal capable of meeting both emission regulations at the power complex. An analysis of these strategies indicated that the MCCS would produce substantial operating, maintenance, effluent disposal, and boiler operating cost savings when compared with installation of an FGD system on Unit 3. The MCCS was therefore selected by the owners as the best technology for complying with SO_2 emission regulations at the power station.

Construction of a MCCS plant designated as the "93 plant" was completed in 1978. The plant design employed a number of innovative coal cleaning techniques which had not previously been used in commercial operation. The cleaning circuits within the plant were more complex than in previous plants and some equipment in the plant was designed for operation at more stringent conditions than previously employed.

The "93 plant" was never able to clean coal to the conditions specified in the plant design. An extensive test and evaluation program designed to identify and correct the causes of plant operating problems ensued. After pilot plant, equipment tests, and engineering studies were completed, recommendations were made on

plant modifications needed to correct the design and operating deficiencies of the plant. Extensive modifications were made to one of the two parallel cleaning trains in the plant (the "B" circuits) and a test program was started in 1982 to evaluate these corrective measures.

This report provides a chronicle of the plant history, describes the design and operating problems of the 93 plant, summarizes the corrective actions taken, and provides some preliminary results of tests on a modified portion of the 1982 plant.

The work described herein includes activities sponsored by the U.S. Environmental Protection Agency (EPA), the Electric Power Research Institute (EPRI), the Department of Energy (DOE), the Pennsylvania Electric Company (Penelec), and the New York State Electric and Gas Corporation (NYSEG).

CONCLUSIONS

Experience over the past six years at the Homer City Coal Cleaning Plant has indicated that cleaning medium and fine size coal at low specific gravity is possible, with a good potential for recovering fuel that is remarkably free of ash and pyritic sulfur contaminants. However, in order to successfully reach full potential, it is necessary to closely control the feedstock to the cleaning devices, to specially engineer the cleaning devices for their specific coal cleaning function, and to maintain close control over the operation of those devices in the plant circuits.

Operation of the coarse coal circuit in the Homer City application has always been considered successful. Coarse coal that is being cleaned at high specific gravity is immune to minor process variations and cyclone design deficiencies because only drastic changes in the gravity and efficiency of separation will produce noticable changes in the quality and quantity of the product.

Successful operation of any coal cleaning process is extremely dependent on the characteristics of the complete coal reserves that will be cleaned. A system that meets or exceeds coal quality specifications when operating on coal from one reserve when mined in one limited area may not perform nearly as well when operating with coal from an over- or underlying seam or in a distant part of the same seam. Coal reserve washability characteristics are variable, depending on deposition environment and subsequent geological history. The range of washability characteristics is especially critical in low specific gravity cleaning processes or those that combine the low and high gravity processes.

Future applications of coal cleaning to meet extremely low ash and sulfur criteria should be proposed with sufficient lead time to extensively sample the reserve bases proposed for the operation and to test the cleaning efficiency of the low specific gravity device on coal that is representative of those reserves. Plant design

should be careful to provide accurate classification, sufficient separating equipment capacity, and a system to efficiently by-pass fine coal that cannot be processed. Since it appears that separating efficiency at low specific gravity is enhanced using fine magnetite in the system, the magnetite recovery equipment must be optimized to recover as much of the fine magnetite as possible to avoid excessive magnetite losses.

BACKGROUND

Coal Preparation Technology

Coal preparation or benefaction is used to remove mineral matter from coal. Historically, the major motivation for these activities has been to reduce the ash level in steam coals and the ash and sulfur levels in metallurgical coals. Since the advent of sulfur emission regulations, many development activities have focused on coal desulfurization.

A number of different unit operations are employed in coal preparation. They include size reduction, size classification, coal cleaning, dewatering and drying, and pollution control/waste disposal. Modern commercial coal preparation plants crush coal and separate the particles into a number of size ranges: coarse, medium, and fine. Each size fraction is processed in common or separate circuits using equipment suitable to the size range and cleaning objectives. Following cleaning, the coal is dewatered and sometimes thermally dried. Pollution control/waste disposal techniques are employed as needed to meet environmental regulations (1).

Size Reduction

Size reduction liberates mineral impurities and produces the range of sizes needed in subsequent cleaning activities. Size reduction is accomplished by mechanical equipment which breaks the coal by impaction, compression, splitting, shearing, or attrition. Energy usage is minimized by staged crushing and by-passing fines.

Equipment used for size reduction may include single or double roll crushers, rotary breakers, and ring-roller mills. Primary size reduction is generally accomplished by rotary breakers or crushers; the second and third stages generally use crushers or mills.

Size Classification

Size classification is commonly used for the removal of fines prior to size reduction or for separation of size ranges prior to further processing or sale. The major size classification technique used is screening. It may be performed in either a wet or dry state. Screens may be stationary or moving. The screening surface may be a perforated plate, a woven cloth, formed bars, or non-stationary parallel bars. The most common screens used in coal preparation are perforated plate and square-opening wire screens that shake or vibrate. These dynamic screens are used to stratify the coal bed and separate the smaller particles which are presented to the screen apertures. Curved stationary screens called sieve bends are used to separate fine and intermediate size particles in water slurries. Classifying cyclones are also commonly used to segregate fine coal particles.

Cleaning

The equipment most commonly used for physical cleaning relies on differences in the size, shape, and specific gravity of particles. Hydraulic washers, dense medium separators, and air concentrators are classes of equipment used in the specific gravity separation of coal.

The most popularly used hydraulic washers are jigs, hydrocyclones, and concentrating tables. Jigs are used to remove mineral matter and mining refuse from coarse and intermediate size coal. The jig is operated by applying periodic hydraulic pulsations to stratify a bed of coal and gangue materials. The heavy refuse materials are removed from the bottom of the bed and clean coal particles are removed from the top. Jigs can process large quantities of coal at low cost, but they do not efficiently separate coal and mineral particles whose specific gravity is nearly the same (near-gravity material). If a large portion of the coal mineral matter and pyrite is contained in the near-gravity material, then ash and sulfur removal efficiencies suffer.

Wet concentrating tables (Deister tables) are vibrating ribbed surfaces onto which a slurry of raw coal is fed. Segregation takes place along the surface so that various regions of the table contain relatively different amounts of coal and mineral particles of different sizes and specific gravities. Concentrating tables are generally used to wash intermediate to fine size coal ranging from 3/8 in. to 200 mesh (9.5 to 0.075 mm). Tables can be used effectively for separating coal and pyrite particles. While the separating efficiencies of tables are good, they require more floor space than hydrocyclones of equivalent capacity.

Hydrocyclones are also used to process medium or fine size coal, however, the underflow (refuse) normally contains a high amount of misplaced coal, which must be recovered by further processing. Additionally, hydrocyclones require a large amount of water for operation. Despite these drawbacks, hydrocyclones have gained wide acceptance, as they can process large tonnages for a relatively low capital investment.

Dense medium separators include dense medium vessels and dense medium cyclones. The bulk of coal cleaned by dense medium processes is cleaned in a suspension of magnetite, although organic liquids, dissolved salts in water, aerated solids, and sand/water suspension have been used on an experimental or commercial basis. Specific gravity (s.g.) denotes the density of the separating media in relation to the density of water (1.0 s.g.). Dense medium vessels are static (laminar-flowing) baths in which particles are separated by virtue of differences in their specific gravity. The use of magnetite (5.0 s.g.) permits parcticle suspension specific gravities from 1.3 to 3.0. For coal coarser than 1/4 in. (6.3 mm), the separation efficiency and energy recovery are between 95 percent and 99 percent of the values expected from laboratory float-sink tests.

The dense medium cyclone circuit is one of the most efficient techniques for cleaning intermediate and fine size coal. A sharp separation of coal and minerals is achieved for all particle sizes above 28 mesh (0.60 mm). Below 28 mesh (0.60 mm) particle separation efficiency deteriorates with decreasing particle size.

In the dense medium cyclone (DMC), a slurry stream containing sized coal, water and very finely ground magnetite is fed under pressure through an orifice to form a high velocity stream that enters the cyclone chamber tangentially, near the top of a cylindrical section, thus forming a strong vortical flow (Figure 1). The refuse moves along the wall of the cyclone and is discharged through the underflow orifice. The washed coal moves toward the longitudinal axis of the cyclone and passes through the vortex finder to the overflow chamber (see Figure 2). The washed coal is discharged from this chamber through either a tangential or axial outlet pipe. In addition to the cyclone, the DMC circuit must also contain equipment for preparing and controlling the medium (water/magnetite slurry) and recovering magnetite for reuse. Thus a DMC circuit normally contains a magnetite feed system, a dense medium sump, one or more dense medium cyclones, drain and rinse screens, and magnetic separators.

The increased costs of constructing and operating dense medium circuits are generally offset by improvements in the product coal quality and recovery efficiency.

Equipment using air as a separating medium has been used for cleaning coal with sizes ranging from 3/8 in. to 48 mesh (9.5 to 3.0 mm). However, the use of this equipment has declined because of problems with separating wet coal and the cost of controlling dust emissions from the process.

Performance Criteria

A number of criteria are traditionally used to evaluate the performance of coal cleaning equipment. The various criteria are usually classified according to the degree to which they depend on the characteristics of the coal being cleaned. Some are dependent, either directly or indirectly, and some are, under certain circumstances, essentially independent.

Dependent Criteria

Equipment performance criteria that depend on the properties of the coal being cleaned are called dependent criteria. Dependent criteria used in the report include (2):

Weight Yield - The ratio, expressed in percentage, of the weight of clean coal divided by the weight of the feed coal.

Btu Recovery - The ratio, expressed in percentage, of the total calorific value of the clean coal divided by the total

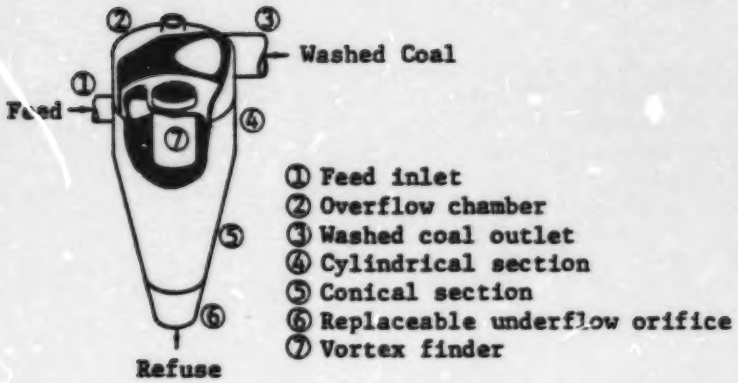

Figure 1. Dense Media Cyclone (From Coal Preparation: reproduced with permission of the American Institute of Mining, Metallurgical and Petroleum Engineers)

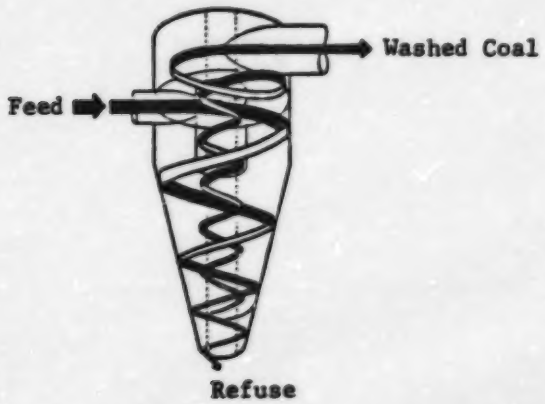

Figure 2. Cyclone Flow Pattern (From Coal Preparation: reproduced with permission of the American Institute of Mining, Metallurgical and Petroleum Engineers)

calorific value of the feed coal.

Emission Parameter (of Clean Coal) - The total heat specific SO_2 emission which results when coal is completely combusted and the sulfur is converted entirely to SO_2. The emission parameter is normally expressed in lb $SO_2/10^6$BTU or ng/J.

Emission Reduction - The ratio, expressed as a percentage, of the differential emission parameter (raw coal emission parameter minus the clean coal emission parameter) divided by the raw coal emission parameter.

Recovery Reduction - The ratio, expressed in percentage, of the yield of cleaned coal to the yield of the float coal of the same ash content shown, by the specific gravity analysis, to be present in the feed.

Misplaced Material - The sum of the sink material in the cleaned coal and the float material in the refuse, expressed as a percentage of the raw coal.

Yield Error - The difference between the yield of coal actually obtained and the theoretical yield at the ash content of the cleaned coal obtained.

Ash Error - The numerical difference between the actual and theoretical ash content of cleaned coal at the yield of cleaned coal obtained.

Independent Criteria

Some equipment performance criteria are substantially independent of the coal properties. These independent performance criteria are generally determined from the separation distribution curve. The distribution curve is a plot of the percentage of each specific gravity fraction of the coal feed recovered in the clean coal product versus the median of the specific gravity fraction. The specific gravity of separation is defined as the specific gravity of the material in the raw feed that is divided equally between clean coal and refuse. A typical distribution curve for fine coal is shown in Figure 3. Independent criteria include (2):

Probable Error - An indication of the slope of the distribution curve equal to one-half of the specific gravity difference between the 25 and 75 percent ordinate values on the curve.

Error Area - The area between the actual distribution curve and the theoreticallly perfect distribution curve. The theoretically perfect curve is a step function of the specific gravity of separation (see Figure 4).

Imperfection - Probable error divided by the specific gravity of separation.

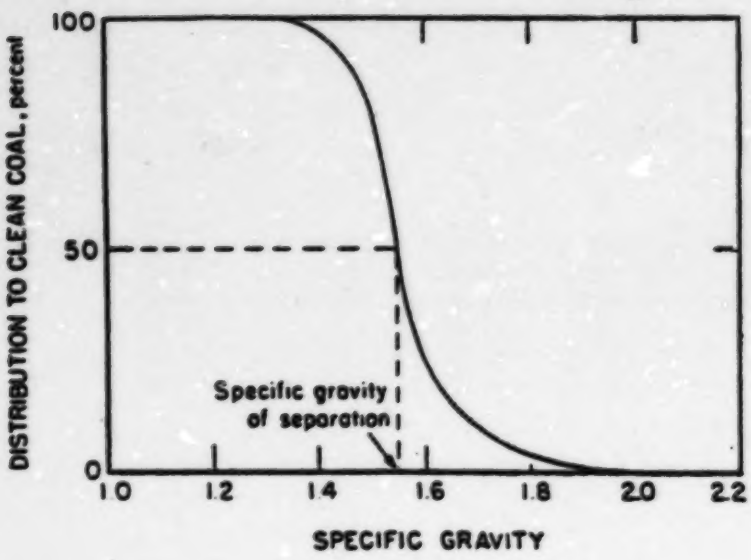

Figure 3. Distribution Curve Showing Specific Gravity of Separation

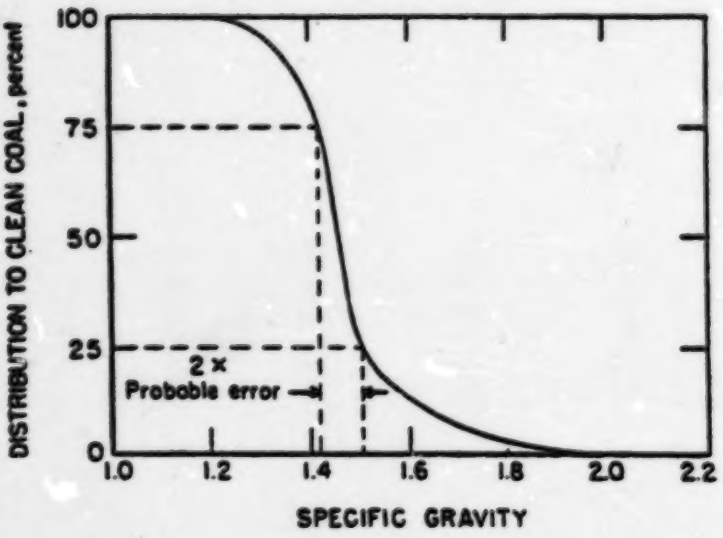

Figure 4. Probable Error

HISTORY OF THE 93 PLANT

Indigenous coal deposits near the Homer City Power Station include the Freeport and Kittanning coal seams. These seams have been recognized as beomg highly susceptible desulfurization by coal cleaning because they contain both a relatively low percentage of chemically bound organic sulfur and a high, but easily liberated, pyritic sulfur. Favorable research findings on coal washing initially encouraged consideration of advanced preparation methods as an alternative to FGD at Homer City.

From a large research, development, and engineering evaluation program conducted by the owners' consultants and Heyl and Patterson, it was concluded that an advanced physical coal cleaning plant would be capable of supplying two different products simultaneously. These two products would supply all the necessary Homer City compliance fuels without supplemental FGD. The technology would provide a 40 percent to 50 percent reduction in the overall SO_2 emission and redistribute the remaining ash and sulfur content of the cleaned coal so that SO_2 emissions of less than 3.7 $lb/10^6$ Btu (1590 ng/J) would result from Units 1 and 2 and less than 1.2 $lb/10^6$ Btu (590 ng/J) from Unit 3.

Economic studies indicated that annual revenue requirements for complying with the SO_2 emission regulations by using clean coal for the existing units and installing an FGD system on Unit 3 would have exceeded $25 million. In contrast, annual revenue requirements for compliance with SO_2 emission regulations in all three units using the MCCS approach would have been less than $14 million.

In August, 1975, the Homer City owners decided to proceed with the design and construction of the initial MCCS, designated the 93 plant (Figure 5). The order for the FGD system was cancelled.

The basic coal cleaning technology initially implemented at Homer City was well established; however, several new process design features and innovations were incorporated into the system, including the following:

- Raw coal crushing was to be controlled to minimize production of the very fine coal that was difficult to recover from the plant process water.

- Dense medium cyclones, commonly employed to perform a gravitational cleaning of sized coal, were used to separate coal and ash at smaller particle sizes and lower specific gravity than normally used in commercial practice.

- Scavenging equipment was incorporated in the fine coal processing circuits to recover approximately 95 percent of the energy in the coal fed to the preparation plant.

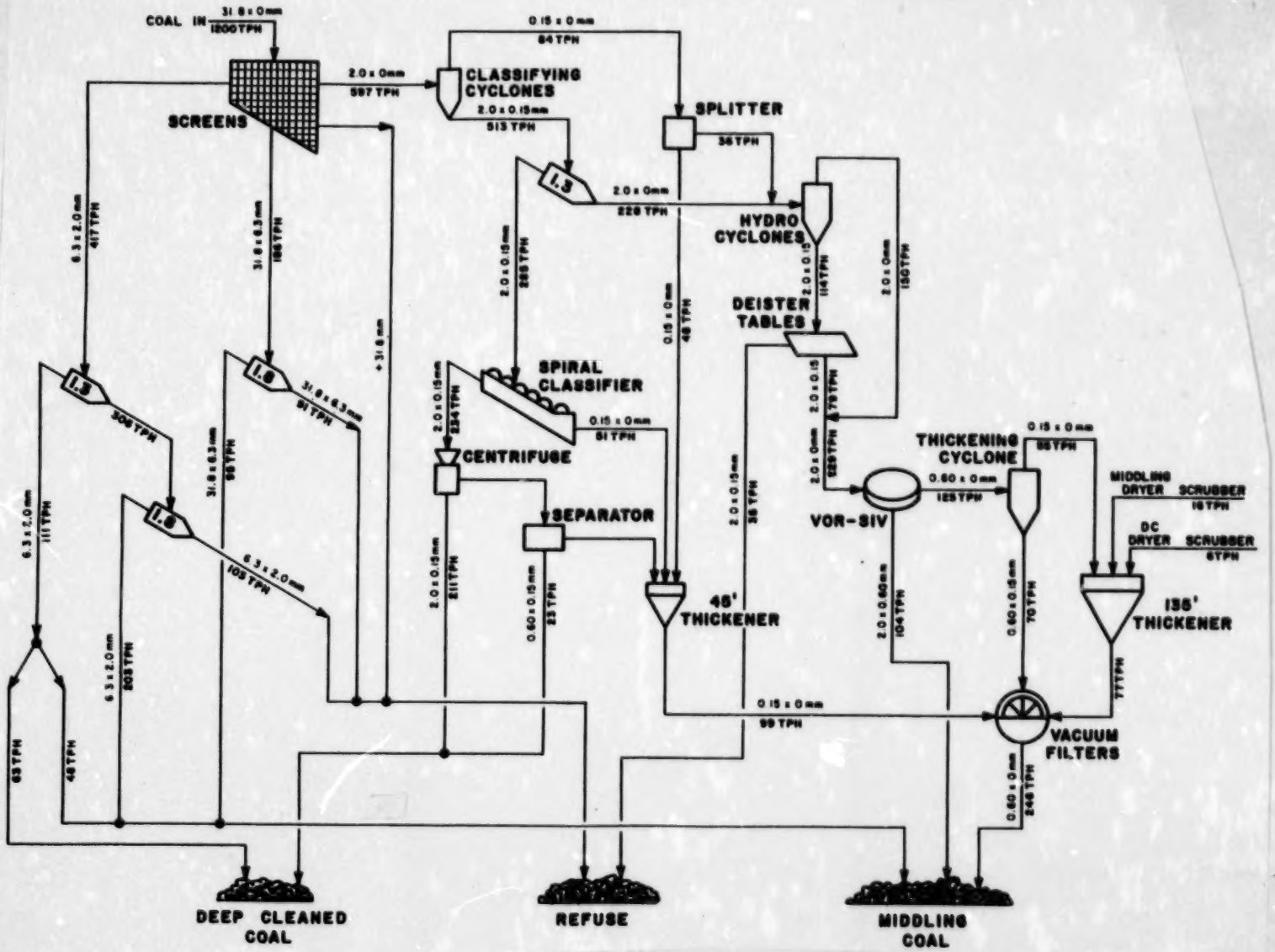

Figure 5. Homer City Coal Preparation Plant (Schematic of 93 Plant)

- Efficient pollution control devices and appropriate methods of residue disposal were employed to minimize the environmental impact of the coal cleaning. The process water was recirculated to provide a closed water circuit without effluent discharges.

One design limitation that influenced the eventual plant construction was that the high gravity section of the system had previously been engineered and had already been drawn up for construction when the decision was made to commit to an integrated, two stage coal cleaning system.

The final design that evolved from this "staged" approach was limited in flexibility by the need to integrate a low gravity, fine coal system into the then existing high gravity circuit designed around a coarse coal process. Compromises in design were necessary to do the integration, and this resulted in a more complex circuit than necessary if circuit integration had been planned at the outset. Problems in equipment organization and lay-out that could be attributed to design evolution plagued the operation of the plant until later remedied by redesign. Had the plant been designed for the multi-stream system from the ground up, it is likely that a simpler, more operable design would have resulted.

DESIGN OF THE 93 PLANT

The configuration of the 93 plant and the anticipated coal flow through the circuits are shown in simplified form in Figure 5. The calculated material balance and coal flow were the product of an engineering and design analysis using coal data from the captive reserves at Homer City Generating Complex. At the time of the design work, it was felt that the detailed washing characteristics of the reserve were stable and there was a sufficient built-in performance margin in terms of recoverable NSPS quality product coal for the system to produce compliance quality products over the life of the generating station. The feed, product and refuse properties for nominal 93 plant design conditions are presented in Table 1.

The 93 plant contained circuits for cleaning coarse, medium, and fine coal. It also contained circuits for the recovery of fine and very fine coal. Little attempt was made to clean the very fine coal.

The dominant type of cleaning equipment used in the plant was the dense medium cyclone (DMC). DMCs were used in the coarse, medium, and fine coal circuits. Hydrocyclones and concentrating (Deister) tables were used to reclean fine coal from the underflow of the fine coal, low gravity DMC circuit. To aid in the recovery of the fine and very fine coal, thickeners were used.

A functional description of the plant is best provided by a circuit by circuit exposition.

Coarse Coal Circuit

The coarse, 1-1/4 x 1/4 in. (31.8 x 6.3 mm) material, projected at 16 percent of the total 1,200 ton (1,089 Mg) per hour feed stream, was processed through 24-in. (61.0 cm) diameter heavy media cyclones at 1.8 s.g.

The overflow from this separation was screened to remove water and the resultant material was used as one component of the middling product for Units 1 and 2. The underflow from the DMC separation was dewatered and discarded as refuse. Most of the refuse material in the coarse coal circuit was originally mined as encapsulated ash "partings" or extra material removed from the floor or roof of the coal seam during mining operations. Because these materials are generally harder and, therefore, not as easily crushed as the organic coal structure, they enter the system as coarse, high-density particles which are easily separated from coal at a high specific gravity.

Medium Coal Circuit

The minus 1/4 in. (6.3 mm) coal that passed through the first raw coal screen was rescreened at 9 mesh (2.0 mm). This material, 1/4 in. x 9 mesh (6.3 x 2.0 mm), projected to be 35 percent of the

Table 1. FEED, PRODUCT, AND REFUSE PROPERTIES FOR THE 93 PLANT

	Plant Feed	Middling Product	Deep Cleaned Product	Refuse
Weight Distribution	100.0	56.2	24.7	19.1
Energy Distribution	100.0	61.6[a]	32.9[a]	5.5
Energy Content, Btu/lb (dry basis)	11,450	12,549	15,200	3,367
Ash Content, percent	23.99	17.75	2.84	69.69
Sulfur Content, percent	2.65	2.24	0.88	6.15
Emission Parameter, lb $SO_2/10^6$Btu	4.64	3.57	1.16	36.54

a. Net energy recovery to be 93.5 percent due to 1 percent energy loss to thermally dry product coals.

crushed raw coal feed, was processed at low gravity to recover a product that would meet or exceed NSPS for Unit 3. This medium size fraction was first fed to DMCs operating at a nominal separating specific gravity of 1.3. At design conditions, 27 percent of the cyclone feed was contained in the overflow. After dewatering, the deep-cleaned product stream was split and 57 percent of the coal was used in the deep-cleaned product and 13 percent was used in the middling product. The underflow from this 1.3 s.g. separation was run through double-drum magnetic separators to remove the specially selected fine magnetite and was reprocessed at high specific gravity (1.8) to recover usable coal for the middling product for Units 1 and 2.

The medium sized coal product from the low gravity circuit was thermally dried to remove excess moisture.

Fine and Very Fine Coal Circuit

Approximately 49 percent of the feed coal was screened out and processed in the fine and very fine coal circuits. The coal first passed through banks of classifying cyclones which separated the fine 9 x 100 mesh (2.0 x 0.15 mm) and very fine 100 mesh x 0 (0.15 mm x 0) material. The cleanable 9 x 100 mesh (2.0 x 0.15 mm) product was processed in 14 in. (35.6 cm) dense medium cyclones installed in banks of eight which discharged overflow and underflow to double-drum magnetic separators to recover the medium. The overflow from the 14 in. (35.6 cm) low gravity cyclones was reclassified using a spiral classifier to remove any very fine coal contamination in the fine coal product. This segregation was necessary because it was expected that coal size degradation or carry-over would dilute the deep-cleaned coal product and adversely affect product quality. The underflow of the 1.3 s.g. DMC separation was recleaned using hydrocyclones and concentrating (Deister) tables. The clean coal from these separations was subsequently dewatered and included in the middling coal product.

Conventional wisdom holds that coal cannot be cleaned well by heavy medium process below 100 mesh (0.15 mm). Therefore, the very fine, minus 100 mesh (0.15 mm) material was segrated and routed to thickeners along with coal contaminated water from the thermal dryer scrubbers. The coagulated coal from the thickener underflow was recovered and dewatered in vacuum filters along with the clean coal middling product from the fine coal circuit.

OPERATION OF THE 93 PLANT

Commercial operation of the 93 plant was scheduled for the spring of 1978. However, because of a number of design problems, the plant never produced the projected quality and quantity of product coal. There were three major problems:

1. Poor water feed to the plant and poor water distribution in the plant made it impossible to run the plant for any sustained period of time and maintain conditions needed for proper equipment operation.

2. The low gravity DMC circuits failed to achieve design performance even when design operating conditions were attained.

3. Magnetite losses in the DMC fine coal cleaning circuits were excessive.

To rectify these problems, an extensive pilot plant and equipment test program was started. Consultants and coal preparation plant architectural and engineering firms were retained to evaluate the plant performance problems and recommend corrective actions.

Pilot Plant Tests

To provide additional data on dense medium cyclone performance a cooperative pilot plant test program was conducted by the DOE, EPA, and the Homer City owners. Thirty-six tests were conducted in the dense medium pilot plant at the DOE Pittsburgh Energy Technology Center (PETC). These tests are documented in Reference 3.

All of the dense medium tests were run with an 8 in. (20.3 cm) diameter dense medium cyclone operated at a nominal feed and at 1.3 s.g. with 9 x 100 mesh (2.0 x 0.15 mm) coal (Figure 6). The operating variables included two inlet orifice sizes, 1.50 in. (38.1 mm) and 1.75 in. (44.5 mm); three medium-to-coal ratios, 7:1, 5:1, and 3:1; and six flow rates, 92, 100, 110, 120, 140, and 160 gpm (348.3, 378.5, 416.4, 454.3, 530.0, and 605.7 l/s). The overflow (clean coal) and underflow (refuse) from each test were divided into three size fractions: 9 x 14 mesh (2 x 1.2 mm), 14 x 28 mesh (1.2 x 0.6 mm), and 28 x 100 mesh (0.6 x 0.15 mm). Each of these size fractions was float-sink tested at eight specific gravities and the resulting increments were analyzed for moisture, ash, and total sulfur.

Pilot Plant Data Analysis

This section details the results of a statistical evaluation of dense medium cyclone test loop performance. Table 2 presents descriptive statistics (mean and standard deviations) for the performance criteria evaluated along with the simple correlations between each criterion and each cyclone operating parameter.

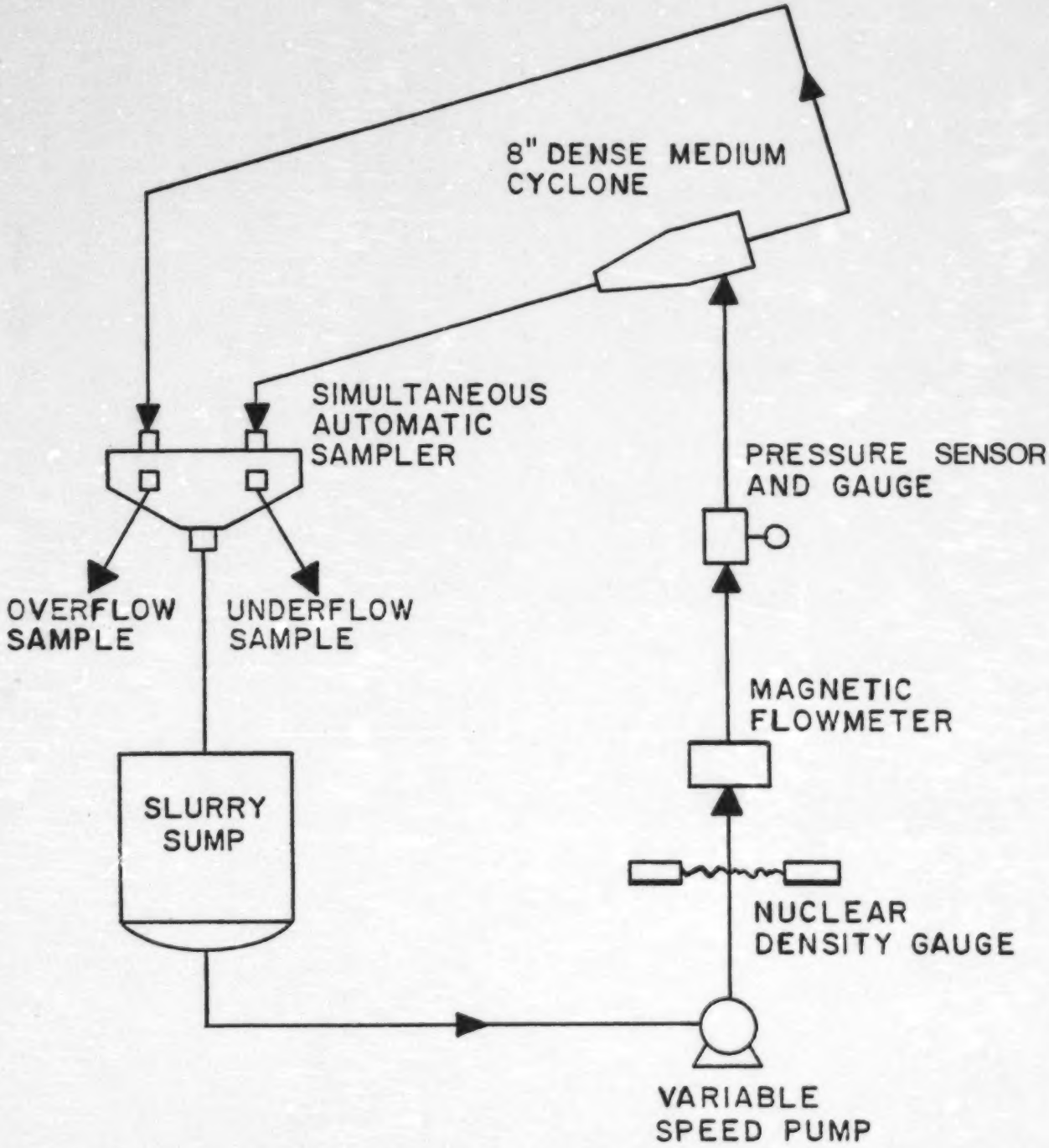

Figure 6. DoE Dense Medium Cyclone Circuit

TALBE 2. MEANS, STANDARD DEVIATIONS, AND CORRELATIONS FOR CYCLONE PERFORMANCE CRITERIA (N = 108)

Criteria	Mean	Standard Deviation	Relative Standard Deviation	Correlations			
				Orifice Size	Flow Rate	Percent Coal in Slurry	Particle Size
Weight Recovery Efficiency	77.96	8.22	0.11	-0.342	-0.108	-0.132	-0.008
Misplaced Material	14.62	3.75	0.26	0.201	-0.173	0.244	-0.615
Ash Error	1.14	0.73	0.64	0.222	0.103	0.240	-0.649
Yield Error	11.44	5.18	0.45	0.301	0.102	0.161	-0.496
Error Area	32.71	22.81	0.70	0.091	-0.036	0.176	-0.826
Probable Error	0.042	0.03	0.71	0.053	-0.043	0.233	-0.799
Imperfection	0.129	0.08	0.62	0.055	-0.049	0.203	-0.803
Percent Sulfur in Clean Coal	1.00	0.15	0.15	-0.002	0.019	0.196	-0.200
Percent Sulfur Reduction	68.50	9.30	0.14	0.059	-0.504	-0.215	-0.249
Normalized Percent Sulfur Reduction	75.65	7.90	0.10	0.065	-0.515	-0.223	-0.120

After doing a more extensive statistical analysis of the test cyclone data, Bituminous Coal Research, Inc. reached a number of conclusions that characterize cyclone operation at low gravity with fine coal. These conclusions as summarized from Reference 2 are presented below.

- Dense medium cyclone performance improves as particle size of the feed coal increases.

Particle size is found to be statistically related to cyclone performance for all criteria examined, except weight recovery efficiency and normalized percent sulfur reduction. Generally, best performance occurs for the 9 x 14 mesh (2.0 x 1.8 mm) size range and deteriorates as particle size decreases. Only in the case of percent sulfur reduction is this tendency reversed; i.e., slightly higher percent reductions occur as particle size decreases. When percent sulfur reduction is normalized for Btu value, this particle size effect is not observed.

- Cyclone performance, as measured by the dependent criteria and percent sulfur reduction, is statistically related to flow rate level.

Flow rate is a statistically significant predictor of cyclone performance as measured by the four dependent criteria and percent sulfur reduction. In all cases, this relationship is best characterized using a second-order polynomial expression for flow rate. This is due to the fact that cyclone performance improves with increasing flow rate up to a value of 120 gpm (454.3 l/s), then deteriorates as the flow rate increases beyond this value. Based upon the flow rate levels examined in the test matrix and the statistical models derived in this investigation, 120 gpm (454.3 l/s) appears to produce the overall best results for the criteria mentioned above. It is possible, however, that the true optimal flow rate is slightly higher or lower than 120 gpm (454.3 l/s).

- Cyclone performance, as measured by the dependent criteria, is related to the size of the inlet orifice.

Inlet orifice size is found to be statistically related to the dependent measures of cyclone performance. In all cases, performance is slightly improved when a 1.5 in. (38.1 mm) orifice is used.

- Dense media cyclone performance improves as the percent coal in the slurry decreases.

Percent coal in slurry is a statistically significant predictor of all measures of cyclone performance examined, except weight recovery efficiency. In general, best performance occurs at a nominal medium-to-coal ratio of 7:1 and deteriorates as the percentage of coal in slurry increases. This tendency is most pronounced for independent measures of cyclone performance.

- The cyclone operating parameters investigated are, in general, more highly correlated with independent measures of cyclone performance than with dependent or sulfur-based criteria.

A comparison of the results obtained for the various performance criteria reveals that a major portion of the variability (over 80 percent) in the independent measures can be accounted for through a knowledge of the operating parameters being considered. In contrast, among the dependent and sulfur-based measures, variability explained by the operating parameters generally ranges from about 25 to 70 percent. (In the case of sulfur in clean coal, less that 10 percent of the variability is explained; however, this is a poor measure of sulfur performance.)

These results are not surprising when one considers that error area, probable error, and imperfection are essentially independent of the washability characteristics of the raw coal. As such, these criteria are more characteristic of the performance of the coal cleaning unit, itself. However, some important and consistent relationships between operating parameters and dependent criteria have emerged from this evaluation. The observed correlations between cyclone operating parameters and the performance measures do indicate particular operating conditions under which cyclone performance is likely to be improved.

- For the test matrix under investigation, cyclone operating conditions corresponding to Test No. 84 (Table 3) appear to produce best overall cyclone performance.

The results of all statistical analyses performed in this investigation suggest that there is one area of the test matrix that is optimal or very near optimal for all cyclone performance criteria examined. The operating conditions of Test No. 84; i.e., 1.5 (38.1 mm) in. orifice size, 120 gpm (454.3 l/s) flow rate, and 7:1 medium-to-coal ratio, seem to produce improved cyclone performance as compared to other operating configurations. While true optimal performance may not occur exactly at the conditions of Test NO. 84, generally this is the best set of operating conditions in the test matrix under consideration.

The results and conclusions of this evaluation are strictly applicable to 8 in. (20.3 cm) cyclones. Generalizations of these results to larger or smaller cyclones should be made with caution. Values of specific operating parameters used in this investigation, such as inlet orifice sizes and flow rates, may not be appropriate for larger or smaller cyclones.

TABLE 3. TEST 84 DATA SUMMARY (2)

	Mesh Size			
	9x14	14x28	28x100	9x100
Screen Analysis, percent				
Feed Coal	28.9	29.8	35.6	94.4
Clean Coal	19.1	30.5	43.3	92.9
Refuse	35.9	29.3	30.2	95.4
Ash, percent				
Feed Coal	34.5	24.5	23.6	24.2
Clean Coal	2.8	3.4	3.7	3.4
Refuse	32.6	40.2	43.9	38.5
Total Sulfur, percent				
Feed Coal	3.61	3.73	5.08	4.20
Clean Coal	1.11	1.16	0.90	1.03
Refuse	4.56	5.63	9.33	6.40
Weight Recovery (Yield), percent	27.4	42.6	50.4	40.9
Theoretical Weight Recovery, percent	23.3	44.0	57.8	43.2
Weight Recovery Efficiency, percent	100.0	96.8	87.3	94.7
Ash Error	0.0	0.1	0.7	0.2
Float in Refuse, percent of product	9.2	16.1	22.7	15.9
Sink in Clean Coal	14.0	9.4	5.9	13.9
Total Misplaced Material, ercent of Feed	10.5	13.2	14.2	15.1
ear Gravity Material	59.7	65.7	65.4	64.0
Specific Gravity of Separation	1.292	1.306	1.351	1.308
Probable Error	0.018	0.021	0.071	0.027
Imperfection	0.063	0.068	0.203	0.088
Error Area	11.	13.	40.	23.
Distribution, percent to Clean Coal (Specific Gravity Fraction):				
Float 1.27	85.7	87.6	85.2	86.1
1.27-1.29	70.0	80.5	86.8	80.0
1.29-1.32	30.2	53.2	77.3	53.9
1.32-1.35	4.6	14.9	58.7	24.6
1.35-1.40	0.6	0.4	37.2	13.6
1.40-1.50	0.0	0.0	23.4	7.2
1.50-1.60	0.0	0.0	12.1	3.6
1.60-1.80	0.0	0.0	0.0	0.0
Sink 1.80	0.0	0.0	0.0	0.0

EVALUATION OF THE 93 PLANT

When it became apparent that the failure of the plant to meet the design performance specification was more than just a start-up problem, a number of eminent cleaning plant consultants and engineering firms were consulted. Each was requested to survey the existing plant and to propose corrective measures to achieve compliance coal quality and production from the deep cleaning circuit, while retaining production and quality in the high gravity circuit. Simon Carves, Ltd.; the United Kingdom National Coal Board, through its U.S.A. licensee, Ebasco Services; Kaiser Engineers; EPRI; and the DOE all evaluated the circuits or parts of them over a six month period to propose a number of integrated changes necessary for proper plant operation consistent with washability characteristics of the coal being processed.

In order to support each of these efforts, a number of plant tests were run on equipment and sub-circuits, under the direction of the various consultants. Eventually, the National Coal Board was chosen to redesign the coarse coal and high gravity circuits and Kaiser Engineers were contracted to revise the fine coal, low gravity circuits.

Coarse Coal Circuit

Some difficulty was experienced in getting an even distribution of crushed coal between the raw coal screens, and problems were encountered due to surging feed and improper wetting of the coal before screening. Each of these problems contributed to screening inefficiencies that altered the distribution of material to downstream circuits and affected their performance.

When the feed to the DMCs in the coarse coal circuit was properly controlled, very little trouble was encountered in cleaning the 1-1/4 x 1/4 in. (31.8 x 6.3 mm) coal to produce a middling product meeting design specifications. The cleaning techniques had been proven in the industry and the coal in this size fraction was as cleanable as originally projected.

Medium Coal Circuit

A number of problems plagued the operation of medium coal, low gravity circuit. Distribution of the feed between screens, and thus among cyclones, proved to be a difficult problem during any long-term run. Also, the screens were at times overloaded causing considerable quantities of fine coal to be intermixed with the medium size screened coal intended for the circuit. Magnetic separators that were responsible for recovering and recycling magnetite had a record of high magnetic material loss while entraining much fine coal in the recirculating magnetite system. All of these recurring problems resulted in poor efficiency of separation in the 14 in. (35.6 cm) dense medium cyclones, poor product quality feed to the deep-cleaned coal circuit, and extremely high loss of magnetite for each ton of coal processed. Magnetite

losses in this circuit ranged between 20 and 40 lb (9.1 and 18.2 Kg) per ton of processed coal while the design loss was calculated at only 3 to 5 lb (1.4 to 2.3 Kg) per ton. This circuit, then, represented a substantial obstacle to the goal of producing an acceptable quantity and quality of coal for Unit 3 at the power station.

Fine and Very Fine Circuit

Some of the problems encountered in this circuit proved insurmountable using the installed equipment. Distribution between cyclones in each bank was a primary problem followed by density control, build-up of very fine coal in the DMC circuit, and misclassification of fine and very fine coal. Because of these and other problems, it was difficult to determine which cyclone orifices would provide satisfactory DMC performance. To solve these and other problems, a 14 in. (35.6 cm) cyclone test loop was set up on-site to sample the flow streams and to allow experimentation with various conbinations of cyclone performance variables. Controlled performance tests on the 14 in. (35.6 cm) cyclone were run to develop a program that would improve cyclone operation. Repeated trials in this test loop pointed out some of the problems described above, but because of the circuit location with respect to its feed coal classifying devices, solutions to these problems proved extremely difficult.

1982 PLANT CONFIGURATION

The "B" side of the 93 plant was extensively modified and started-up in 1982. These modifications were based on pilot plant tests, equipment tests in the 93 plant, and extensive engineering design studies. Major plant modifications are described below.

1. The 135 foot (38.0 m) thickeners were modified to incorporate two outlet water lines (instead of one) and additional pumping capacity was added to supply more water to the top of the plant.

2. Head tanks were installed on the roof of the plant to assure a continuous feed of clarified water to the system.

3. Media sumps with static head feed tubes were placed at several locations in the medium and fine coal circuits, replacing pumped slurry feeds at these locations.

4. Mechanical mixers and distributors were installed in sumps and headers, replacing the more passive devices originally used to obtain distribution of coal between equipment installed in parallel flow paths.

5. Surge bins on load cells were incorporated into the raw coal feed system to eliminate surging feed rates from the raw coal belt.

6. The 14 in. (35.6 cm) DMCs in the low gravity, medium coal circuits were replaced with 8 in. (20.3 cm) cyclones. The circular bank of eight, 14 in. (35.6 cm) cyclones was directly replaced by a new in-line bank of fifteen, 8 in. (20.3 cm) units fed from a fifteen foot central feed tube.

7. The coal size distribution in each circuit was modified to narrow the range of particle sizes in the meduim and fine/very fine circuits. Improved equipment performance is expected for the narrower size ranges.

8. Vibrating screens were installed downstream of classifying cyclones in the fine coal circuit as a means of removing any minus 100 mesh (0.15 mm) material which had been misclassified. This was necessary to reduce the amount of very fine coal contamination in the low gravity DMC fine coal circuit.

9. Magnetic separators were redistributed to not only the process product and refuse streams, but to

recover media from concentrated, very fine coal recovery streams as well.

A schematic of the modified "B" circuits as configured in 1982 is shown in Figure 7. A description of the modified circuits follows.

Coarse Coal Circuit

The coarse coal circuit is the same as the one that was operating in the 93 plant, but now it processes coal down to 1/8 in. (3.15 mm) instead of 1/4 in. (6.35 mm). The coarse 1-1/4 x 1/8 in. (31.8 x 3.15 mm) coal is separated at 1.8 s.g. in 24 in. (61.0 cm) cyclones into a middling product and refuse.

Medium Coal Circuit

The major changes in the medium coal circuit were the change of the particle size range from 1/4 in. x 9 mesh (6.35 x 2.0 mm) to 1/8 in. x 16 mesh (3.5 x 1.0 mm) and the recleaning of the low gravity DMC underflow in hydrocyclones and concentrating tables instead of dense medium cyclones.

In the modified circuit, the 1/8 in. x 0 (3.15 mm x 0) material that passes the raw coal screens is rescreened at 16 mesh (1.0 mm). The coarser product of this separation, 1/8 in. x 16 mesh (3.15 x 1.0 mm) is initially cleaned at low gravity in 14 in. (35.6 cm) dense medium cyclones. The overflow from these cyclones is recombined with the coal product of the fine/very fine circuit for feed to Unit 3 after drying. The underflow from these cyclones is recleaned by hydrocyclones and concentrating tables. The recleaned medium-sized coal is combined with products from the coarse and fine/very fine coal circuits to form the middling product.

Fine/Very Fine Coal Circuit

The major changes in the fine coal circuit involve a redefinition of the coal size from 9 x 100 mesh (2.0 x 0.15 mm) to 16 x 100 mesh (1.0 x 0.15 mm), the use of fifteen 8 in. (20.3 cm) cyclones to replace a former bank of eight 14 in. (35.6 cm) cyclones, the use of a low head static feed tube to stabilize inlet pressure, and the use of special screening devices to eliminate the 100 mesh (0.15 mm) "slimes" before processing.

The most critical portion of the MCCS plant is the cleaning devices which process the fine and very fine coal. In the modified circuit, the 16 mesh x 0 (1.0 mm x 0) coal from the second stage of screening is fed into classifying cyclones to remove minus 100 mesh (0.15 mm) material. Any fines that are mistakenly classified into the 16 x 100 mesh (1.0 x 0.15 mm) product are removed by a set of specially vibrated fine coal screens (Derrick screens) with 100 mesh (0.15 mm) openings. These secondary fine screening devices produce a coal feed to the low gravity DMC feed tubes that is contaminated with very little fine coal. After passing over Derrick screens the

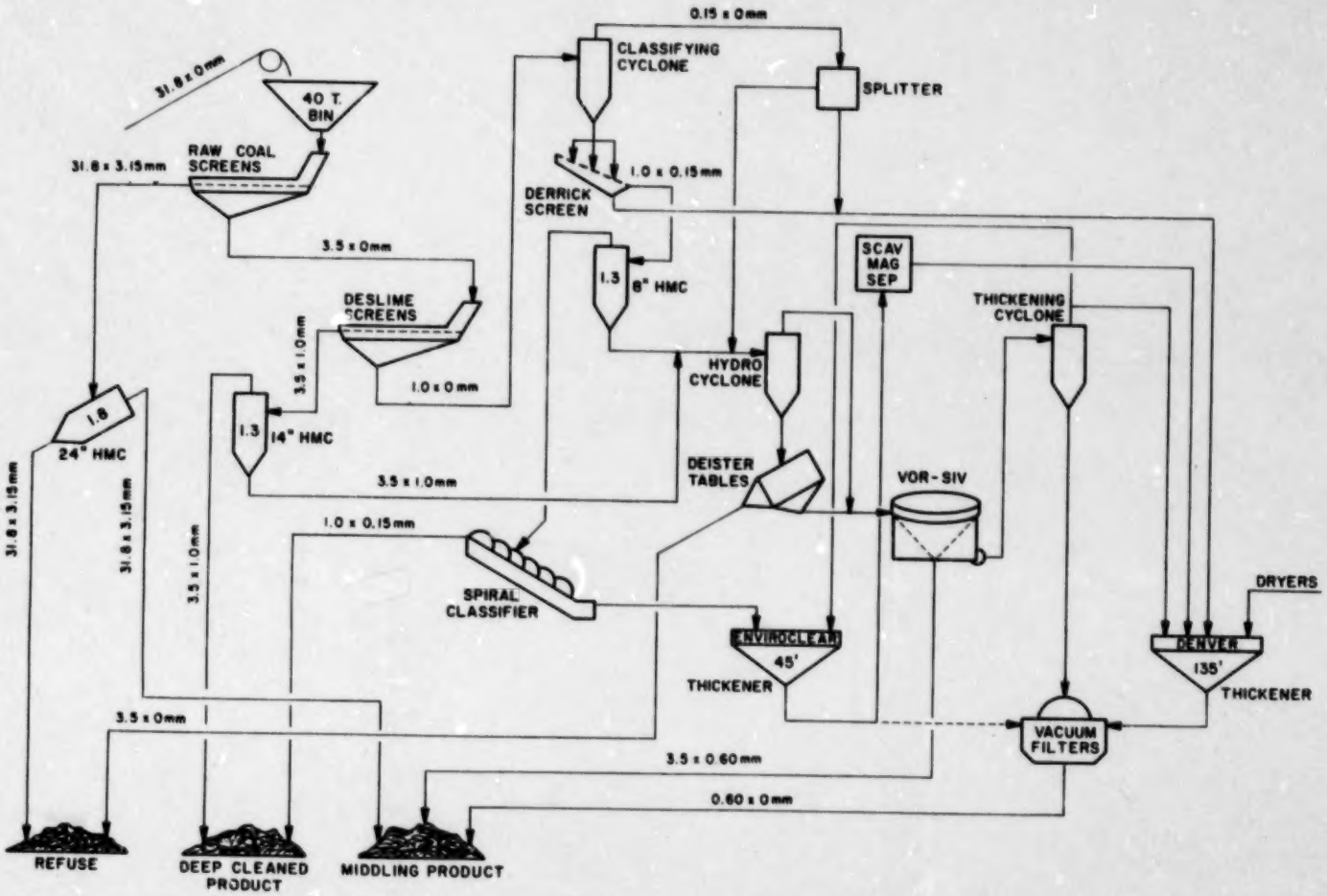

Figure 7. Homer City Coal Preparation Plant (Schematic of "B" Circuits in 1982 Plant)

fine, 16 x 100 mesh (1.0 x 0.15 mm) coal drops into a collecting trough where it blends with medium at approximately 1.3 s.g. and flows into tall columns, each feeding three banks of five 8 in. cyclones. The overflow stream from these cyclones passes through magnetic separators and then to spiral classifiers. The spiral classifiers are used to remove residual fine coal impurities and magnetite. The 150 ton (136 Mg) coal stream is the source of deep-cleaned coal for Unit 3.

Underflow material from the low gravity, fine coal cyclones is fed to hydrocyclones and concentrating tables which reclean the fine coal for use as a middling product. After dewatering, the fine middling coal is blended with the coarse and medium fractions and the combined product is thermally dried.

1982 PLANT PERFORMANCE

The program to test the 1982 plant has centered around the evaluation of the revised low gravity circuits for cleaning medium and fine/very fine size coal. Testing has included that needed for start-up, conceptual design verification, and performance evaluations. Initial test data on the operation of the modified "B" circuits are shown in Table 4 along with corresponding design values.

Medium Coal Circuit

Tests were conducted during the start-up period to optimize performance of the 14 in. (35.6 cm) diameter heavy medium cyclones in the medium coal circuit which operate at low specific gravity. The test results showed that the cyclones fell just short of the targeted quantity and quality requirements necessary to meet design conditions for producing compliance coal from this low gravity circuit. In an effort to pinpoint the problem areas within this circuit, an individual cyclone was modified for further testing. This single cyclone within the bank was sampled under various operating conditions to determine the effects of operating parameters on performance. To date, the most dramatic effects in cyclone performance were observed when the plant medium was purged and recharged with fresh E grade magnetite. (Commercial ground magnetite or Fe_3O_4 for use in heavy medium systems is available in several grades which are determined by the material passing 325 mesh or 0.045 mm screening. The coal preparation industry standard for B grade is 90 percent passing, for E grade 95 percent passing, and for F grade 98 percent passing.) Under these conditions, the performance at 1.34 s.g. separating gravity met the design sharpness of separation criteria (i.e., a probable error of 0.03). Although the design coal quality was not achieved, these results show that the dense medium cyclones can provide sharp separations under appropriate operating conditions. Test work is continuing to evaluate methods of optimizing the performance of these dense medium cyclones at low specific gravity.

Fine Coal Circuit

The 8 in. (20.3 cm) dense medium cyclones in the fine coal circuit clean coal in the size range of 16 x 100 mesh (1.0 x 0.15 mm) at low gravity. Testing was performed on the circuit during January and Febraury, 1982. During this time period, modifications were made to the cyclone banks and operating conditions were varied to measure their effect on circuit performance. Design conditions were not achievable in this circuit using the variations possible, so the testing shifted to a detailed performance analysis of a single cyclone within a five cyclone bank. As with the dense medium cyclones in the medium coal circuit, the most dramatic performance improvement was measured when the plant medium was recharged with fresh magnetite; however, design performance was still not achievable over the available range of operating conditions. At

TABLE 4. COMPARISON OF MCCS B CIRCUITS DESIGN AND CURRENT PERFORMANCE

Designation of Flow Streams	Design Performance[1]					Current Performance[2]				
	Flow Rate, tph	Ash Content, percent	Sulfur Content, percent	Heating Value, Btu/lb	Emission Parameter, $lbSO_2/10^6Btu$	Flow Rate, tph	Ash Content, percent	Sulfur Content, percent	Heating Value, Btu/lb	Emission Parameter, $lbSO_2/10^6Btu$
Feed to B Circuits[3]	600	23.2	2.31	12082	3.82	600	23.9	2.46	11563	4.26
Coarse Coal DMC Feed[4]	198	35.6	2.52	10125	4.98	259	33.0	2.57	9972	5.15
Coarse Coal DMC Product	132	15.9	1.32	13226	1.99	168	13.0	1.51	13432	2.25
Coarse Coal DMC Underflow[5]	66	75.1	4.93	3924	2.51	91	69.7	4.52	3603	25.2
Medium/Fine Coal Circuits (Deslime Screen Feed)	402	17.1	2.21	13047	3.38	341	17.0	2.38	12768	3.72
Medium Coal DMC Feed	180	19.8	2.19	12617	3.47	156	18.0	2.45	12552	3.90
Medium Coal DMC Product[6]	91	4.44	0.95	15034	1.26	60	5.98	1.14	14664	1.56
Medium Coal DMC Underflow[7]	89	35.5	3.46	10146	6.82	96	25.5	3.26	11238	5.80
Classifying Cyclone Feed	222	14.8	2.22	13394	3.31	185	16.1	2.32	12950	3.58
Classifying Cyclone Overflow[4]	48	16.1	2.18	13199	3.30	58	18.4	2.37	12922	3.51
Fine Coal DMC Feed	174	14.6	2.22	13435	3.30	127	15.1	2.34	12963	3.60
Fine Coal DMC Product[6]	104	3.42	0.87	15194	1.14	77	5.60	1.09	14674	1.49
Fine Coal DMC Underflow	70	31.2	4.23	10822	7.82	50	29.8	4.25	10331	8.23
Hydrocyclone Overflow[4]	108	17.1	1.98	13043	3.04	102	14.6	2.03	13122	3.09
Deister Table Feed	51	68.6	7.64	4937	3.10	45	55.1	7.16	5940	24.1
Deister Table Product[4]	13	44.8	4.87	8687	11.2	27	43.0	5.52	8069	13.7
Deister Table Refuse[5]	38	76.8	8.59	3653	47.0	18	73.3	9.62	2808	18.5
Deep Cleaned Product	195	3.90	0.91	15118	1.20	137	5.77	1.11	14670	1.51
Middling Product	301	17.6	1.85	12963	2.85	354	16.6	2.09	12855	3.25
Refuse	104	75.7	6.27	3824	32.8	109	70.3	5.36	3471	30.9

1. Design Performance based on Kaiser Engineers Metallurgical Balance, revised August, 1981.
2. Based on best available data as of 8-1-83, products with Deister Table in operation, new Krebs 10 in. HMC in the First Stage Circuit.
3. Dedicated coal supplies for Homer City Generating Station. Blend of 60/40 Helvetia-Helen, uncrushed. Composite analysis from fifteen week average.
4. To plant middling product.
5. To plant refuse.
6. To plant deep cleaned product.
7. Under flow is recleaned with fine coal DMC under flow.

separating gravities between 1.3 and 1.4 s.g., the cyclone did not produce a sharp separation. Probable errors of 0.06 and 0.10 were measured. Because of these cyclone performance limitations, a clean coal sulfur quality of less than 1.35 lb SO /10 Btu (580 ng/J) could not be produced by the fine coal circuit.

Table 5 is a data sheet from a test of similar 8 in. (20.3 cm) dense medium cyclones surrounding a static feed tube on one of two trees in the fine coal "B" circuit. The engineering design intended all of these cyclones to perform the same because they are located on three manifolds that are spaced at 120 degrees around the feed tube. Each of these manifolds feeds five 8 in. (20.3 cm) dense medium cyclones standing straight upright on their refuse discharge cones. During this sample collection, feed medium gravity was held at 1.40, all cyclones used the same orifice combination, and the circuit was run at rated capacity. Ten of the fifteen available cyclones on one feed tube were sampled from two manifolds. Data are tabulated in the same order that the cyclones are arranged on the manifolds.

In the design flowsheet, the product from those devices is expected to have a 60 percent yield with a quality of 3.42 percent ash, 0.87 percent sulfur, and 15,194 Btu/lb. The refuse from this separation is expected to have a quality of 31.2 percent ash, 4.23 percent sulfur, and 10,822 Btu/lb. Cyclone #2 approached these design performance characteristics with a clean coal ash of 4.7 percent and a "refuse" ash of 31.6 percent at a 63.2 percent yield of clean coal, and was the only cyclone to approach this separating efficiency.

The level of variability between units in the bank containing cyclones 9 through 13 is acceptable, especially considering that the individual cyclones were sampled one after the other, rather that simultaneously. This sequential sampling introduces the fluctuation of feed quality with time into the result. While none of the cyclones in this bank produced yields and quality that even approached the design properties, the cumulative performance of the bank indicates a problem that is common to all cyclones. Potential problems such as cyclone design, orifice combination, feed pressure, cyclone orientation, specific gravity of operation, or magnetite fineness were evaluated in this bank.

The bank containing cyclones numbered 1, 2, 3, 14, and 15 appears as a highly variable operation, with one cyclone that is not performing well at all (cyclone #1). The swing in performance here is beyond the variation caused by changes in feedstock content with time, ranging from performance that approaches specification to the mediocre performance of cyclones in the other bank. Cyclone #1 evidently has a problem in placement and physical component lay-out. Orifice sizes should have been checked; alignment of the inlet line and blockage of orifices may have revealed an installation problem. Changes were made to this "tree" before the analyses were returned from the laboratory. A re-inspection of the installation was not made.

TABLE 5. PERFORMANCE COMPARISON BETWEEN CYCLONES ON ONE FEED TUBE
HOMER CITY COAL PREPARATION PLANT

	Cyclone 3		Cyclone 2		Cyclone 1		Cyclone 15		Cyclone 14	
Sample No.	OF	UF	OF	UF	OF	UF	OF	UF	OF	UF
Coal plus Medium	3092	3093	3094	3095	3096	3097	3098	3099	3100	3101
Characteristics										
Slurry density	1.08	1.52	1.06	1.68	1.16	1.53	1.08	1.72	1.06	1.68
Suspended solids										
Weight, percent	24.35	58.63	14.24	61.09	24.24	59.02	26.15	63.73	20.62	68.53
Size distribution, percent										
1. plus 0.15 mm	69.9	40.9	62.2	21.0	45.5	35.9	65.6	26.5	52.7	38.7
2. minus 0.15 mm	30.1	59.1	37.8	79.0	54.4	64.1	34.4	73.5	47.3	61.3
Magnetics in the -0.15mm percent	48.4	91.8	39.6	94.4	75.0	90.31	45.5	93.1	44.9	91.0
Coal Sized Greater Than 0.15 mm, Dry Basis										
Ash content, percent	6.01	17.86	4.70	31.61	9.75	19.31	5.42	28.64	6.14	18.98
Sulfur content, percent	0.98	1.76	0.95	2.95	1.07	2.10	0.93	2.58	0.94	1.91
Heating value, Btu/lb	14545	12344	14651	10022	13975	12128	14643	12330	14511	12334
lb $SO_2/10^6$Btu	1.35	2.85	1.30	5.89	1.53	3.46	1.27	4.18	1.30	3.10
Magnetics in the -0.15 mm, percent	0.00	0.70	0.00		1.81		0.00	1.11	0.90	0.04

Medium Characteristics at the Head Box	3112	3113	3114	3115	3116
Slurry density	1.38	1.37	1.36	1.34	1.35
Suspended solids, percent	39.53	39.33	39.18	38.46	37.87
Percent magnetics	78.20	78.50	78.40	78.10	77.60
Yield*	23.8	63.2	42.0	59.1	31.8

Test Conditions: Helvetia coal, only; 600 tph; Crusher speed = 150 rpm; Orifices, feed = 1 3/4 in, overflow = 3 1/4 in, underflow = 2 1/4 in; specific gravity measured at the flask = 1.40.

*These yields are calculated using a 14.6 percent feed ash.

TABLE 5 (continued)

Sample No.	Cyclone 13 OF 3102	Cyclone 13 UF 3103	Cyclone 12 OF 3104	Cyclone 12 UF 3105	Cyclone 11 OF 3106	Cyclone 11 UF 3107	Cyclone 10 OF 3108	Cyclone 10 UF 3109	Cyclone 9 OF 3110	Cyclone 9 UF 3111
Coal Plus Medium Characteristics										
Slurry density	1.07	1.58	1.06	1.60	1.07	1.67	1.09	1.71	1.10	1.54
Suspended solids										
Weight, percent	19.09	67.04	15.56	68.65	14.91	69.4	16.53	69.30	19.59	68.79
Size distribution, percent										
1. Plus 0.15 mm	55.9	39.8	62.7	38.6	63.8	42.4	58.7	38.1	53.7	39.9
2. Minus 0.15 mm	44.1	60.2	37.3	61.4	36.2	57.6	41.3	61.9	46.3	60.1
Magnetics in the -0.15mm percent	46.1	89.9	37.14	92.0	46.2	91.2	36.6	92.5	50.8	91.4
Coal Sized Greater Than 0.15, Dry Basis										
Ash content, percent	6.57	17.62	4.58	18.47	8.54	19.4	5.93	18.91	5.01	19.23
Sulfur content, percent	0.93	1.74	0.92	1.84	0.89	2.04	0.94	2.00	0.96	2.04
Heating value, Btu/lb	14450	12569	14777	12354	14152	12173	14660	12386	14685	12374
lb $SO_2/10^6$Btu	1.29	2.77	1.25	2.99	1.26	3.35	1.28	3.23	1.31	3.30
Magnetics in the -0.15mm, percent	1.61	0.40		0.80	3.60	1.31	1.51	0.70		0.70

Medium Characteristics at the Head Box	3117	3118	3119	3120	3121
Slurry density	1.34	1.32	1.33	1.36	1.38
Suspended solids, percent	37.64	37.49	37.54	37.72	37.56
Percent magnetics	77.50	76.70	76.40	76.20	75.70
Yield*	21.9	24.3		27.0	28.8

Due to the wide variation in the performance characteristics of the dependent criteria, sufficient laboratory analysis was not performed to arrive at independent criteria.

The balance of cyclones in this bank should have been checked for physical uniformity, especially the units that were performing reasonably well (cyclones #2 and 15). One explanation of the non-uniformity here may lie in the arrangement of the feed trough to the feed tube as it is located in relation to the offtake for the bank. Segregation of coal characteristics in this slow-flowing feed trough and feed tube should be expected to drop coarser refuse-rich feed near the trough offtake, while transporting the finer and better quality material to the opposite wall. This segregation could then be expected to continue as the coal/medium slurry is carried with little turbulence down the feed tube. If this arrangement proves to be a factor in feed quality, and since cyclones #2 and 15 have the best performance here, cyclone #1 is expected to also perform well when fixed.

These data were taken in 1982 when the 8 in. (20.3 cm) cyclones were first placed in service at the Homer City Coal Cleaning Plant. The test personnel have not done further sampling of this type since a decision was made to concentrate on an individual cyclone's operating characteristics. Further comparative sampling will be done immediately following the supervised installation of new units in this plant circuit.

Present and future work is aimed at determining why the 8 in. (20.3 cm) dense medium cyclone at the Homer City Coal Cleaning Plant behaves so differently from the pilot plant cyclone tested at the DOE facility in Bruceton, Pennsylvania. Future plant testing will investigate the effects of cyclone geometry, inlet pressure, cyclone orientation, finer-sized magnetite, medium-to-coal ratio, and coal size distribution on the performance of 8 in. (20.3 cm) cyclone. Arrangements are now being concluded to switch cyclones between the operating cleaning plant circuit and the Bruceton test loop with the intent of confirming the DOE's work in the plant and providing a more controlled test set-up for the plant cyclones.

PLANS FOR FUTURE ACTIVITIES

The existing "B" circuits at the Homer City Coal Cleaning Plant are not yet operating at their design conditions, but there is a requirement for a system to produce compliance quality coal in the quantities necessary to support a 650 MW generating unit. In attempting to meet this requirement for full two-circuit production of cleaned coal as soon as possible, the owners have commissioned a conceptual design that will avoid any obvious problems with the existing "B" circuit and will refine that design a step further. Some modifications that are being considered to improve plant performance are:

1. The possibility of incorporating a magnetite grinding circuit to re-size the coarser fraction of the magnetite supply that is preferentially recovered from the circuit product and refuse streams.

2. A high-gradient magnetic separator that will be capable of recovering fine-sized magnetite from the coal streams.

3. An improved cyclone design that performs more like the 8 in. (20.3 cm) cyclone originally tested by DOE at Bruceton.

4. Improved blending of coal supplies to permit easier batching or blending of washable truck coal supplies through the plant.

5. Possible changes to the feed size distribution between the coarse and fine coal low gravity circuits.

6. Changes to the feed tube arrangement to permit a higher pressure introduction of slurry into the cyclone.

Further controlled tests of these variables at DOE-Bruceton, the Homer City Coal Cleaning Plant cyclone test loop, and EPRI's Coal Cleaning Test Facility near the cleaning plant will help the designers of the "A" circuit to make a judgment of the relative merits that each of these improvements has in meeting the 1.2 lb SO_2 /10 Btu^6 (516 ng/J) quality coal.

Even though the Homer City Coal Cleaning Plant has had to undergo several design and a multitude of operational changes before the objective clean coal quality could be approached, these efforts have provided some leadership to encourage other potential users of the technology. Through the owners' intensive testing in conjunction with EPA, EPRI, and DOE, some of the factors influencing cleaning plant performance have been quantified and addressed in a commercial-scale cleaning plant. The magnitude of advances that have been made and the potential of even newer methods to selectively separate coal from impurities, point the way to future

systems that will economically segregate sulfur and ash impurities before combustion, to substantially improve the operation of the combustion unit and necessary supplemental emission control equipment.

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